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ENVIRONMENT CANADA
1989 CINOLA PROJECT
BASELINE STUDIES

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by

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ABSTRACT

A monitoring program was conducted between August and September 1989 to establish baseline conditions of water and sediment quality in streams adjacent to a proposed gold mine. Juvenile coho salmon that had been caged *in situ* for six weeks appeared to be an effective monitoring tool by which to establish baseline conditions of mercury availability. Feral juvenile coho salmon were also tested for muscle mercury content.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

In June 1988, City Resources (Canada) Limited submitted a Stage II Report to the Provincial Mine Development Steering Committee (City Resources, 1988). The report outlined the proposed development of an open pit gold mine (Cinola Gold Project) on Graham Island, Queen Charlotte Islands, British Columbia. The mine would be located within the Yakoun River drainage which has significant fishery resources (Brown and Musgrave, 1979).

As part of a Cinola Gold Project pre-development data collection program, Environment Canada (Environmental Protection), undertook a monitoring program in August and September 1988 (Derksen, 1989). The program focused on using *in situ* caged juvenile coho salmon to establish baseline conditions from which to assess the effects on fish of potentially elevated environmental metal levels and other changes in water quality resulting from future mining activity. Water and sediment samples were collected in order to characterize the study streams. Feral juvenile coho salmon were also sampled to compare to the caged fish.

The second year of baseline studies was initiated in August and September 1989. *In situ* caged juvenile coho salmon were maintained in the same locations as in 1988. One additional station was added in 1989. A centrifuged suspended sediment sample was also collected for mercury analysis. This report presents the results of the 1989 study.

2.0 STUDY AREA

The Yakoun River drains an area of approximately 477 square kilometres flowing in a northerly direction and draining into Masset Inlet near Port Clements, B.C. (Figure 1).

The tributary streams that could be potentially impacted most by the Cinola Project include Barbie Creek (including Barbie Wetland) and Florence Creek (Figure 1). Barbie Creek drains the area surrounding the ore body (open pit) and is proposed to receive various mine related discharges (settling ponds, treated acid mine water). Upper Florence Creek has been identified as the location for the tailings impoundment. Barbie Creek drains into the Yakoun River approximately 29 km upstream of Yakoun Bay while Florence Creek drains into the Yakoun Bay estuary.

2.1 Sample Sites

Three sites were located on Barbie Creek. The Lower Barbie site (lb) was located at the downstream end of the Barbie Creek wetland and the middle Barbie site (mb) was located upstream of the wetland (Figure 2). A new site (bw) was established within the wetland. Gold Creek (g), which drains into the Yakoun River approximately 4 km upstream of Barbie Creek, was selected as a reference stream (Figure 1). One site was monitored on Florence Creek (fl) for water quality only (Figure 1). Water samples were collected from the Yakoun River (ykn1) for total mercury analysis only.

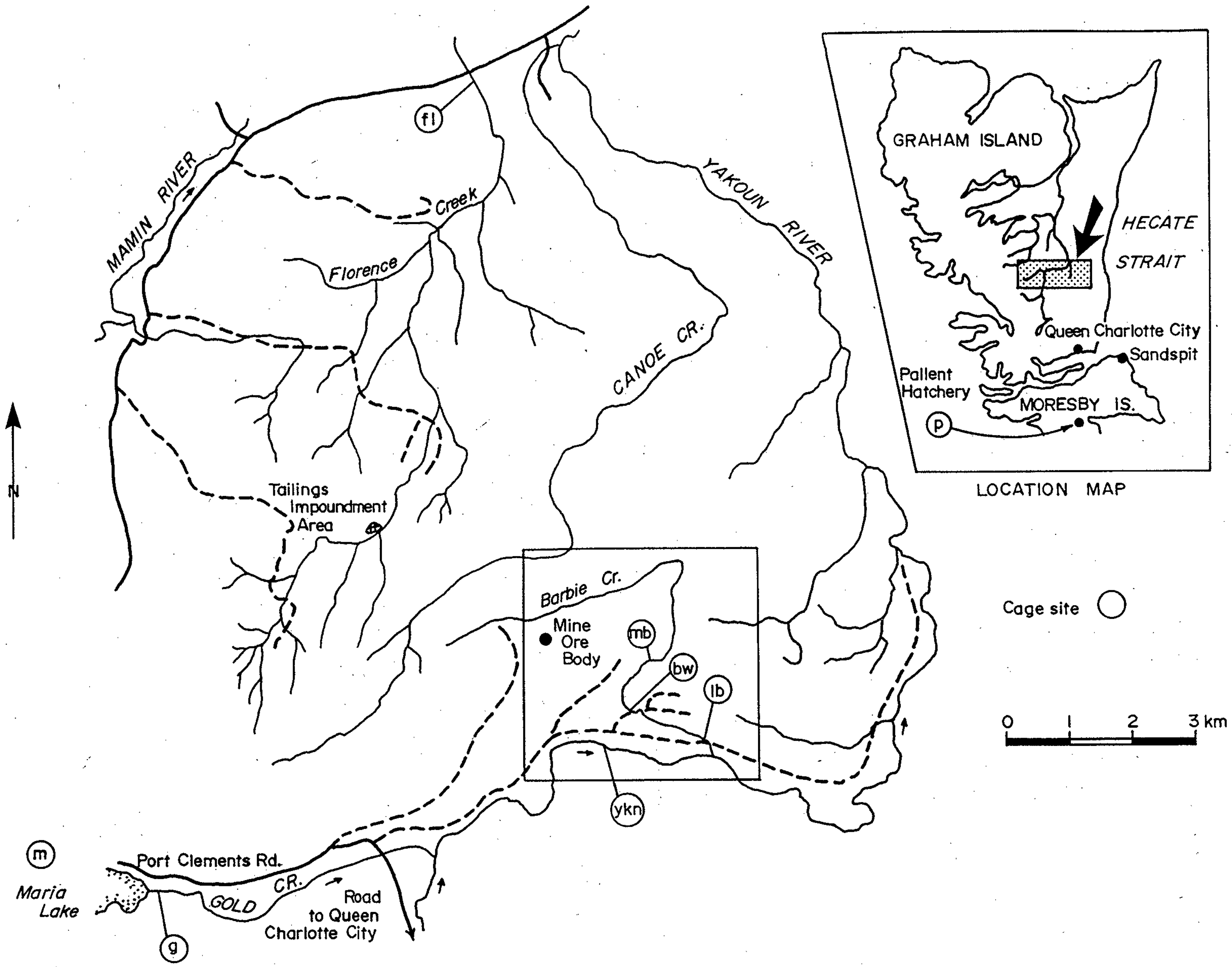


FIGURE 1: Juvenile Coho Salmon Caging Sites - 1988 and 1989.

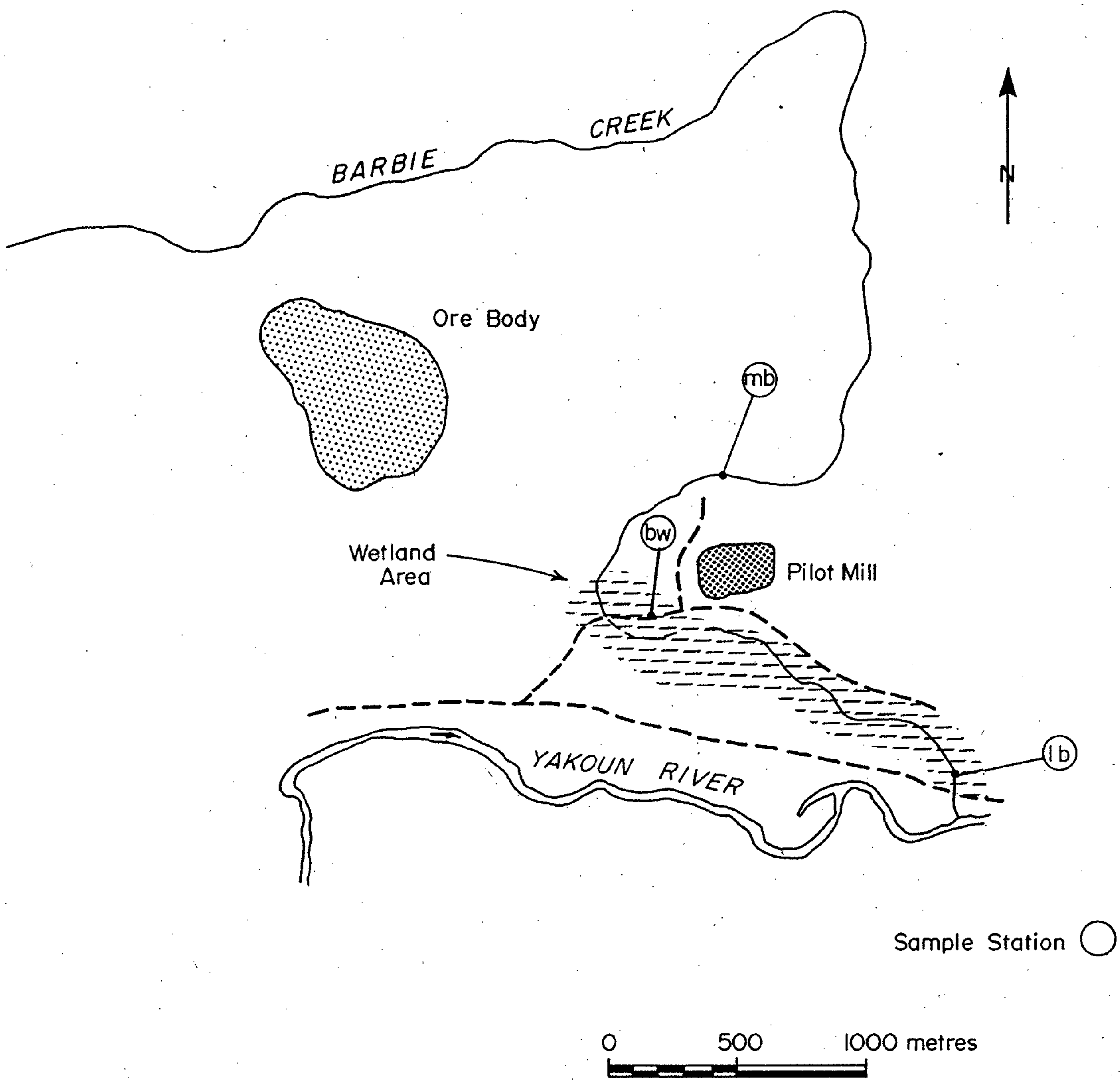


FIGURE 2: Barbie Creek Study Area and Sample Sites - 1989.

TABLE 1: **SAMPLE SITE DESCRIPTION**

SAMPLE SITE **(Figures 1 & 2)**	**DESCRIPTION**
Lower Barbie Creek (lb)	- Lower end of Barbie Creek wetland, approximately 50 m upstream of Branch 40 road crossing. - Slow flowing channel containing pieces of tree debris (logs, bark, and branches) and with an organic substrate.
Barbie Wetland (bw)	- Eastern end of the drainage channel on north side of Branch 40A road. - Slow flowing channel draining upper end of wetland and with an organic substrate.
Middle Barbie Creek (mb)	- Upstream of Barbie Creek wetland. - Generally slow flowing channel with fallen tree debris and with a generally sandy substrate.
Florence Creek (fl)	- Approximately 45 m upstream of Main Line road bridge crossing. - Gravel/sandy substrate.
Gold Creek (g)	- Approximately 50-75 m downstream of Marie Lake outlet. - Generally slow flowing section of creek with fallen tree debris and with an organic substrate.

3.0 MATERIALS AND METHODS

3.1 Surface Water Quality

Grab samples were collected in clean sample bottles and treated as described in Table 2. Disposable laboratory gloves were worn while the samples were being collected. Triplicate samples were collected for metal analyses. Distilled water blanks were also submitted for metal analysis quality assurance.

Dissolved total phosphorus and dissolved ortho-phosphorus samples were filtered through 0.45 μm cellulose acetate membrane filters which had been soaked and rinsed in distilled water. Dissolved metal samples were filtered through 0.45 μm cellulose nitrate membrane filters into clean sample bottles within six hours of collection. Phosphorus samples were filtered immediately in the field.

Samples were shipped in coolers with ice to the Environment Canada, West Vancouver Chemistry Laboratory. Analytical methods are summarized in Table 3 (Environment Canada, 1989).

Samples for copper complexing capacity and humic acid content were collected in 1 L amber glass bottles. Complexing capacity was determined by CBR International Corp. (Appendix VI).

Temperature was measured with either a hand-held thermometer or using a digital readout Hydrolab Model 4041 instrument. Dissolved oxygen samples were determined by Winkler titration or measured directly with the Hydrolab 4041 or a YSI dissolved oxygen meter.

TABLE 2: SURFACE WATER SAMPLE CONTAINERS AND TREATMENT

ANALYSIS		SAMPLE BOTTLE & PRESERVATION
Immediates:		
alkalinity	-	200 ml poly, cold.
acidity		
pH		
chloride	-	1000 ml poly, cold.
sulfate		
specific conductance		
residue		
(non-filterable)		
(total volatile)		
turbidity		
sulfide	-	100 ml glass, 0.5 ml 1M zinc acetate & 0.5 ml 0.5M sodium bicarbonate, cold.
total carbon		
(organic/inorganic)	-	100 ml glass, cold.
dissolved oxygen	-	300 ml glass BOD, 2 ml manganese sulfate & 2 ml azide solution, cold.
nitrogen		
(total)	-	200 ml poly, cold.
(ammonia)		
(nitrite)		
(nitrite/nitrate)		
phosphorus		
(total)	-	60 ml glass.
(dissolved)	-	60 ml glass.
Metals:		
total and dissolved	-	100 ml acid washed poly, 0.5 ml nitric acid.
mercury		
(total)	-	100 ml acid washed poly, 5 ml potassium dichromate-nitric acid.
(total low level)	-	1000 ml acid washed poly, 10 ml potassium dichromate-nitric acid.

TABLE 3: **SURFACE WATER SAMPLE ANALYTICAL METHODS**

PARAMETER (Detection Limit)	METHOD
Immediates:	
alkalinity (1 mg/L)	- Potentiometric titration with sulphuric acid to pH 4.5.
acidity (1 mg/L)	- Potentiometric titration with standard alkali to pH 8.3.
pH (0.1)	- Potentiometric, pH meter.
chloride (0.05 mg/L)	- Colourimetric, mercuric thiocyanate-ferric nitrate combined reagent.
residues (5 mg/L)	
(non-filterable)	- Gravimetric, Whatman GFC filtered and dried at 105°C for one hour.
(total volatile)	- Gravimetric, evaporated at 75°C overnight and then dried at 105°C for one hour, loss on ignition at 550°C.
turbidity (0.1 FTU)	- Nephelometric turbidity.
total organic/inorganic carbon (mg/L)	- Combustion, infra-red.
dissolved oxygen (0.1 mg/L)	- Winkler titration.
phosphorus (2 μg/L)	- Total and dissolved. Colourimetric, persulphate-autoclave digest, molybdate-ascorbic acid reduction. - Dissolved ortho. Colourimetric, molybdate-ascorbic acid reduction.
nitrogen	
total (0.02 mg/L)	- Colourimetric, persulphate-autoclave digest, cadmium/copper reduction.
ammonia (5 μg/L)	- Colourimetric, phenolhypochlorite.
nitrite (5 μg/L)	- Colourimetric, diazotization.
nitrite/nitrate (5 μg/L)	- Colourimetric, cadmium/copper reduction.

TABLE 3 (CONT'D): SURFACE WATER SAMPLE ANALYTICAL METHODS

PARAMETER (Detection Limit)	METHOD
Metals: (total and dissolved). Total metal samples (except mercury) are autoclave digested with 3:1 nitric: hydrochloric acid for two hours. Mercury samples are oxidized by the addition of 2:1 sulphuric:nitric acid, 3% potassium persulfate and heated for one hour at 105°C.	
Ag (0.1 μg/L)	graphite furnace atomic absorption.
Cd (0.1 μg/L)	graphite furnace atomic absorption.
Cu (0.5 μg/L)	graphite furnace atomic absorption.
Pb (0.5 μg/L)	graphite furnace atomic absorption.
As (0.5 μg/L)	ICP emission spectrometry-hydride.
Se (0.5 μg/L)	ICP emission spectrometry-hydride.
Al (0.05 mg/L)	ICP emission spectrometry-hydride.
Ca (0.1 mg/L)	ICP emission spectrometry.
Fe (5 μg/L)	ICP emission spectrometry.
Mg (0.1 mg/L)	ICP emission spectrometry.
Mn (1 μg/L)	ICP emission spectrometry.
Si (0.05 mg/L)	ICP emission spectrometry.
Zn (2 μg/L)	ICP emission spectrometry.
Hg (0.05 μg/L)*	cold vapour atomic absorption.
hardness (mg/L)	calculated from dissolved metal sample.

* detection limit of 0.005 μg/L when 1000 ml sample evaporated (hot plate boiled) to 1/10th volume.

3.2 BOTTOM SEDIMENT

Sediment samples were collected with a 3.5 cm ID acrylic core tube. A wooden dowel with a rubber bung fixed to the end of it was used to extrude the sediment. Between stations, the sample equipment was rinsed with 70% ethanol and distilled water and either air-dried or wiped dry with a paper towel.

3.2.1 **Heterotrophic Bacteria and Redox**. A single sediment sample made up of a composite of three cores was collected for heterotrophic bacteria analysis. A sterile plastic spoon was used to transfer the sediment into a sterilized polyethylene sample bottle. The samples were kept cold and shipped to the Environment Canada Microbiology Laboratory in North Vancouver. The analytical methods were identical to those used in 1988.

Three sediment core samples were collected for redox potential analysis. After collection, the core sample was allowed to settle for approximately two minutes. The sample was then slowly extruded to within 1 cm of the top of the core tube. The top 1 cm of water and surficial sediment was then poured into a clean 50 ml polyethylene centrifuge tube and capped. Redox measurements were made with a Metrohm model E588 pH/Redox meter within five minutes of the samples being collected.

3.2.2 **Mercury**. A single sediment sample made up of a composite of eight cores was collected at each site on August 30, 1989. The top 2 cm of each sediment core was extruded into a clean stainless steel bowl. The sediment in the bowl was thoroughly mixed and then transferred with a sterile plastic spoon into a Kraft paper sediment bag for volatile residue, total nitrogen, and total mercury analyses, or a whirl-pac bag for methyl mercury analysis. Sediment samples were frozen in the field with dry ice. The methyl mercury samples were subsequently dewatered.

Sediment sample analyses and analytical methods are summarized in Table 4. With the exception of methyl mercury, the samples were analyzed at the Environment Canada West Vancouver Laboratory (Environment Canada, 1989) Methyl mercury analyses were performed at the National Hydrology Research Institute Saskatoon (Jackson, 1988).

3.3 SUSPENDED SEDIMENT

A single continuous flow suspended sediment sample was collected at a site draining the Barbie wetland by using an Alfa Laval suspended sediment centrifuge sampler. A single sample was collected for methyl mercury analysis by centrifuging for twelve hours at a flow rate of 4 L/min. The sample was immediately frozen in the field with dry ice.

TABLE 4: SEDIMENT ANALYSES AND ANALYTICAL METHODS

PARAMETER	METHOD
Volatile Residue	- Samples oven dried at 90°C overnight, oven dried at 103°C for one hour and then muffled at 500°C for one hour. - Gravimetric analysis.
Heterotrophic Bacteria	- Surface or plate count on heterotrophic plate count agar.
Total Nitrogen (0.05 mg/g)	- 0.015-0.03 g sample, persulphate autoclave digestion for one hour. - Colourimetric, cadmium/copper reduction.
Methyl Mercury	Samples dewatered by: - thawing overnight in a cold room (4°C). - decanting the clear water component. - centrifuging in clean 50 ml polyethylene centrifuge tube a known weight of wet sample for 2 minutes at 1600 rpm. - decanting the clear water and reweighing the sample. - re-freezing. - sample analysis performed at the National Hydrology Research Institute Saskatoon.
Total Mercury	- Cold Vapour Atomic Absorption.

3.4 Fish Studies

3.4.1 Caged Fish Emplacement and Sampling. Lake pen-reared juvenile coho salmon (mean weight 4.6 g) were obtained from the Marie Lake hatchery located on Graham Island on the Queen Charlotte Islands. Circumstances did not permit the use of the same Pallant Creek hatchery stock utilized in 1988.

Test fish were transported directly from Marie Lake net pens to the study sites in 60 L coolers with ice packs placed beneath polyethylene liners. The coolers were oxygenated during transport to the Barbie Creek sites. Cages were constructed of 13 mm x 13 mm vinyl coated metal Aqua Mesh screen lined with 7 mm Vexar mesh to prevent escapement. Dimensions were 30.5 cm x 30.5 cm x 122 cm for a volume of 110 L. The cages were steam cleaned prior to use.

Test sites were characterized by slow current velocities and were judged to be less than the previous years' flows (i.e., <11 cm/sec.). Forty fish were placed in each cage for a loading of approximately 1.8 g/L, The cages, one per site, were suspended above stream bottom and just below the water surface. The fish were fed three times a week with Biodiet, a commercial fish ration, at a rate of approximately 4.3% of the total cage fish wet weight per feeding. The single ration was dispensed in approximately five minutes by sprinkling over the upstream end of the cage. Cages were checked for mortalities and cleaned with a plastic bristle brush after each feeding. Fish were held in situ for forty-two days, from August 2 to September 13, 1989.

Whole fish samples were collected for tissue analyses from Marie Lake net pens (Day-0) to serve as a reference. These fish had been held separately in a cage and not fed for 36 hours prior to sampling. The study site fish were sampled after six weeks of caging (Day-42). Marie Lake net pens were resampled after six weeks. All fish were held for at least 24 hours without feeding prior to sampling. Individual fish were placed in labelled whirl-pac bags and immediately stored in coolers with dry ice. The samples were subsequently stored at -20°C until required for analysis.

3.4.2 **Caged Fish Tissue Preparation and Analyses**. Eight samples of muscle tissue per site were analyzed for total mercury. The fish used in 1989 were smaller than those used in 1988 necessitating a composite of four fish per sample, rather than individual fish, as was the case in 1988. In preparation for dissection, the fish were partially thawed, wiped clean with Kimwipe tissue paper and measured for length (to the closest 0.1 cm) and weight (to the closest 0.1 g). Dissection tools were rinsed in 5% nitric acid, followed by deionized water, then dried with Kimwipe tissue paper during and between dissections. Scalpel blades and rinse solutions were renewed between each test site group. Muscle tissue was dissected from above the lateral line, removing all skin and bone, and refrozen in polyethylene ziplock bags until analysis at the Environment Canada West Vancouver Laboratory.

Sample moisture content was determined by weighing the sample before and after freeze-drying. Freeze-dried samples were then ground and nominal 0.3 g samples were weighed into teflon vessels. Nitric acid (5 ml) was added and samples were left to sit for one hour. Samples were then microwave digested (720 Joules/sec.) for 18 minutes, cooled and volumized with 1 ml of hydrochloric acid and 20 ml of deionized water. Samples were transferred to acid-washed 30 ml polyethylene bottles and allowed to de-gas for one week prior to analysis. Total mercury was analyzed by cold vapour atomic absorption spectrometery. Certified reference samples of TUNA-50 muscle tissue were used to determine mercury recovery at the laboratory.

The relative proportion of methyl mercury to total mercury was determined on a whole fish sample. Each sample was made up of a composite of three whole fish with the exception of Gold Creek (Day-42) which was a composite of two whole fish. The Barbie wetland and mid-Barbie sites were not analyzed for methyl mercury. Total and methyl mercury samples were analyzed by cold vapour atomic absorption spectrometry.

Lipid analysis was performed on whole fish samples (n=5) for all reference and caged sites. A modification of the methanol-chloroform extraction method was used for lipid analysis (Bligh and Dyer, 1959). Lipid analyses were performed by Syndel Laboratories, Vancouver.

An ICP metal analysis was performed on a single composite sample, from each site, made of the livers from the fish used in the total mercury portion of the study (n=4).

3.4.3 **Feral Fish Collection**. Feral juvenile coho salmon were collected between September 12-14, 1989 from Barbie wetland (bw) and Gold Creek (g) using salmon roe baited G-traps. The largest juvenile coho were retained, placed in individual labelled whirl-pac bags, and immediately frozen in a chest cooler containing dry ice. Samples were handled in an identical manner as the caged fish.

3.4.4 **Feral Fish Tissue Preparation and Analyses**. Feral fish preparation and analysis was the same as for the caged fish. The 1989 feral fish were treated identically to the 1988 study in that each of the samples was a composite of two dissected fish. Liver samples from all of the Barbie wetland site fish were composited for metal analysis.

Feral juvenile coho from Gold Creek were analyzed only for methyl and total mercury. The single sample analyzed was a composite of three whole fish.

4.0 RESULTS

4.1 Surface Water Quality

Water quality results for the five stream stations (Lower Barbie, Barbie Wetland, Mid-Barbie, Lower Florence, and Gold Creek) are reported in Appendix I(a) for non-metals and Appendix I(b) for metals. Total and dissolved zinc results have not been reported as the deionized water reference blanks indicated an inexplicable contamination problem throughout the study.

Stream velocities were not measured in 1989 but were visibly lower than velocities in 1988 (i.e., less than 11 cm/s) as were water levels. Water levels and flows were monitored by the mining company's consultant.

4.2 Sediment Quality

Sediment quality results for Lower Barbie, Barbie wetland, mid-Barbie and Gold Creek are reported in Appendix II.

4.3 Juvenile Coho Salmon Muscle Tissue Mercury

4.3.1 **Caged and Feral Fish**. The whole fish results for total and methyl mercury (and moisture content) are reported in Appendix III(a). Composite muscle tissue (mercury and moisture content) results are reported in Appendix III(b) along with associated reference tissue results. Weight, length, condition factor and lipid results for representative fish used in the caged study are reported in Appendix III(c). The condition factor was calculated as 100 times wet weight (g) divided by length (cm) cubed (Reimers, 1963).

The metal analysis of composite livers with associated reference tissue results are reported in Appendix III(e).

4.4 Food Ration Quality

The quality of food ration used for control and test fish is reported in Appendix IV.

4.5 Fish Transportation

Water temperature, dissolved oxygen, and percent saturation conditions at the beginning and end of fish transport to the study sites on August 2, 1989 appears in Appendix V.

5.0 DISCUSSION

5.1 Surface Water

Water quality characteristics of the study sites for 1989 are summarized in Table 5 and the 1988 results are reported in Table 6 for comparative purposes. The humic nature of Barbie and Florence Creek relative to Gold Creek is apparent in their higher organic carbon, volatile residue, lower pH and higher acidity content. Florence Creek is somewhat intermediate in humic nature between the Barbie and Gold Creek systems. Barbie and Florence Creeks both drain adjoining low lying areas while Gold Creek drains Marie Lake (Figure 1). The nature of organic carbon in natural waters has been described by Thurman (1985).

Barbie and Florence Creeks also showed higher total and dissolved phosphorus, total nitrogen, chloride and sulphate levels relative to Gold Creek. Florence Creek was again intermediate between Barbie and Gold Creeks with respect to these parameters.

All of the streams were characterized by low alkalinity and hardness. Barbie Creek had very low dissolved oxygen saturation levels while Florence and Gold Creek had levels of 95.6% and 107.2%, respectively. Mean water temperatures were highest in Gold Creek (18.1°C) while Barbie and Florence Creek temperatures ranged from 12.8°C to 14.8°C.

Water temperature was consistently higher for Gold Creek in both years, possibly due to the warm outflowing surface waters of Marie Lake. Dissolved oxygen saturation levels in Barbie Creek were almost twice as high in 1988 (71-84% saturation versus 35.7-40.1% in 1989). The low dissolved oxygen values observed in 1989 are likely a function of the much lower stream flows observed in that year compared to 1988.

The low level total mercury levels reported in Appendix I(b) indicated detectable levels at some time for all stream stations. The high mean value observed for mid-Barbie (Table 5) was due to a single high outlying value [see Appendix I(b)]. Arsenic was detectable at all station except for Florence Creek, with mid-Barbie having the highest mean value. Total copper values in 1989 were above detection for all stations except Gold Creek, whereas all stations were less than detection in 1988. Cadmium means were above detection levels for Barbie Creek in 1989 but not in 1988. Zinc values are not reported due to inexplicable blank deionized water contamination problems. Iron and aluminum levels were higher in Barbie and Florence Creek than in Gold Creek; the same trend was observed in 1988. The copper complexing capacity was highest for lower Barbie Creek (122.6 μg/L) and least for the Yakoun River (28.9 μg/L) (Appendix VI).

TABLE 5: SUMMARY OF MEAN WATER QUALITY CHARACTERISTICS OF BARBIE, FLORENCE, AND GOLD CREEKS - 1989

NON-METALS (mg/L)	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
pH	6.8	6.5	6.8	7.2	7.3
acidity	3.4	5.6	4.8	2.7	1.4
alkalinity	10.2	10.1	13.0	14.5	12.9
hardness (mg/$CaCO_3$)	14.6	15.5	19.0	13.4	14.2
chloride	9.8	9.8	9.8	7.2	4.9
conductivity (µmhos/cm)	63	60	67	56	50
sulphate	10	11	11	6	3
T-Phosphorus (µg/L)	77	65	77	38	5
TD-Phosphorus (µg/L)	50	43	41	31	3
ammonia (µg/L)	73	47	71	62	20
nitrite (µg/L)	5	5	<5	<5	<5
nitrite + nitrate (µg/L)	9	<5	<5	<5	<5
T-Nitrogen	640	623	630	290	127
TOC	27	28	28	16	4
TIC	2	3	5	2	2
NFR	7	10	9	<5	<5
vol. res.	63	75	74	48	23
Temp. (°C)	14.8	13.8	12.8	13.8	18.1
DO	3.5	3.8	4.1	9.6	9.8
oxygen sat. (%)	35.7	38.5	40.1	95.6	107.2

METALS (µg/L)	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
T-Hg (ng/L)	13	12	37	11	7
T-Ag	-	-	-	-	-
D-Ag	-	-	-	-	-
T-As	8.0	7.0	10.3	<0.5	0.7
D-As	7.1	5.8	11.9	<0.5	1.1
T-Se	0.8	<0.5	0.7	0.7	<0.5
D-Se	0.6	<0.5	<0.5	0.6	<0.5
T-Cu	0.8	0.8	1.3	0.8	<0.6
D-Cu	<0.5	0.8	0.6	<0.5	<0.5
T-Cd	0.3	0.2	0.2	<0.1	<0.1
D-Cd	<0.1	0.2	0.1	<0.1	<0.1
T-Pb	<0.6	<0.6	<0.6	<0.6	<0.6
D-Pb	<0.5	<0.5	<0.5	<0.5	<0.5
T-Zn					
D-Zn					
T-Ca (mg/L)	3.6	3.7	4.8	2.7	4.6
D-Ca (mg/L)	3.5	3.8	4.7	2.7	4.4
T-Mg (mg/L)	1.5	1.5	1.8	1.6	0.8
D-Mg (mg/L)	4.27	1.5	1.8	1.6	0.8
T-Fe (mg/L)	1.98	3.79	4.83	0.87	0.13
D-Fe (mg/L)	0.454	1.96	2.70	0.040	0.06
T-Mn (mg/L)	0.362	0.160	0.500	0.027	0.026
D-Mn (mg/L)	0.61	0.144	0.473	0.31	0.014
T-Al (mg/L)	0.30	0.64	0.64	0.19	0.06
D-Al (mg/L)	0.37	0.42	0.43		<0.05

T = Total
D = Dissolved

TABLE 6: **SUMMARY OF MEAN WATER QUALITY CHARACTERISTICS OF BARBIE, FLORENCE AND GOLD CREEKS - 1989**

NON-METALS (mg/L)	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
pH	6.8	6.5	6.8	7.2	7.3
acidity	3.4	5.6	4.8	2.7	1.4
alkalinity	10.2	10.1	13.0	14.5	12.9
hardness (mg/$CaCO_3$)	14.6	15.5	19.0	13.4	14.2
chloride	9.8	9.8	9.8	7.2	4.9
conductivity (μmhos/cm)	63	60	67	56	50
sulphate	10	11	11	6	3
T-Phosphorus (μg/L)	77	65	77	38	5
TD-Phosphorus (μg/L)	50	43	41	31	3
ammonia (μg/L)	73	47	71	62	20
nitrite (μg/L)	5	5	<5	<5	<5
nitrite + nitrate (μg/L)	9	<5	<5	<5	<5
T-Nitrogen	640	623	630	290	127
T-Organic Carbon	27	28	28	16	4
T-Inorganic Carbon	2	3	5	2	2
NFR	7	10	9	<5	<5
volatile residue	63	75	74	48	23
Temperature (°C)	14.8	13.8	12.8	13.8	18.1
DO	3.5	3.8	4.1	9.6	9.8
oxygen sat. (%)	35.7	38.5	40.1	96.4	107.2

METALS (μg/L)	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
T-Hg (ng/L)	13	12	37	11	7
T-Ag	-	-	-	-	-
D-Ag	-	-	-	-	-
T-As	8.0	7.0	10.3	<0.5	0.7
D-As	7.1	5.8	11.9	<0.5	1.1
T-Se	0.8	<0.5	0.7	0.7	<0.5
D-Se	0.6	<0.5	<0.5	0.6	<0.5
T-Cu	0.8	0.8	1.3	0.8	<0.6
D-Cu	<0.5	0.8	0.6	<0.5	<0.5
T-Cd	0.3	0.2	0.2	<0.1	<0.1
D-Cd	<0.1	0.2	0.1	<0.1	<0.1
T-Pb	<0.6	<0.6	<0.6	<0.6	<0.6
D-Pb	<0.5	<0.5	<0.5	<0.5	<0.5
T-Zn	**	**	**	**	**
D-Zn	**	**	**	**	**
T-Ca (mg/L)	3.6	3.7	4.8	2.7	4.6
D-Ca (mg/L)	3.5	3.8	4.7	2.7	4.4
T-Mg (mg/L)	1.5	1.5	1.8	1.6	0.8
D-Mg (mg/L)	1.5	1.5	1.8	1.6	0.8
T-Fe (mg/L)	4.27	3.79	4.83	1.64	0.13
D-Fe (mg/L)	1.98	1.96	2.70	0.87	0.06
T-Mn (mg/L)	0.454	0.160	0.500	0.040	0.026
D-Mn (mg/L)	0.362	0.144	0.473	0.027	0.014
T-Al (mg/L)	0.61	0.64	0.64	0.31	0.06
D-Al (mg/L)	0.30	0.42	0.42	0.19	<0.05

T = Total; D = Dissolved
** Not reported due to contamination

5.2 Sediment

Sediment quality characteristics for Barbie and Gold Creek are summarized in Table 7. Lower Barbie Creek had the lowest median redox level and the highest heterotrophic bacteria count. The lower volatile residues for mid-Barbie reflected the coarser, more sandy nature of that site. The lower organic nature of these sediments would account for the lower methyl mercury value (<0.0001 $\mu g/g$) observed for mid-Barbie sediment (Appendix II). Conversely, Barbie wetland had the highest volatile residue and the highest levels of methylated mercury. The correlation between organic nutrient substrate and mercury methylation has been documented by Jackson (1988). In addition, the low dissolved oxygen values observed in 1989 would serve to enhance the methylation process.

5.3 Fish Studies

The caged fish appeared to be in good condition physically and there was no evidence of fin or body abrasion. The Barbie wetland and mid-Barbie sites both had three mortalities, while Gold Creek had one mortality. The higher mortality incidence within the Barbie system may have been due to the low dissolved oxygen levels observed there (Table 5); however, no mortalities were reported at the Lower Barbie site. Observations of stomach contents revealed that the fish were eating aquatic insects in addition to the ration.

Indicators of fish condition are reported in Table 8. It can be seen from these data that while control fish (Marie Lake Day-42) showed an increase in fork length, weight, and condition factor, the caged fish did not relative to Marie Lake Day-0. The caged fish also showed a significant decrease in lipid content and a significant increase in percent moisture content, while the control fish did not. An increase in percent moisture content and a concurrent decrease in lipid content suggests the fish were in a state of physiological transition, possibly reflecting acclimation from the lake to stream environment. This was likely exacerbated by low flows and low dissolved oxygen conditions in the Barbie Creek system. Derksen (1991) reported on the possible significance of lipid and moisture content changes in caged fish and starvation conditions.

TABLE 7: **SUMMARY OF SEDIMENT QUALITY CHARACTERISTICS OF BARBIE AND GOLD CREEKS**

STUDY SITE	Redox (mv) (median)	Hetero. Bact. (CFU/g)	T-N (μg/g)	Vol. Res. (%)	T-Hg (μg/g) dry wt.	Me-Hg (μg/g) dry wt.
Lower Barbie	+80	775,000	6,500	34.90	0.286	0.0010
Barbie Wetland	+150	270,000	12,000	60.80	0.220	0.0025
Mid-Barbie	+150	148,500	670	2.96	0.068	<0.0001
Gold Creek	+100	120,000	6,600	41.60	0.160	0.0014

TABLE 8: **INDICATORS OF FISH CONDITION**

STUDY SITE FISH	Fork Length (cm)	Weight (g)	Cond. Factor	% Lipid	% Moisture
Marie Lake:					
Day-0	7.7 (0.4)	5.1 (0.6)	1.1 (0.1)	9.71 (0.99)	77.2 (0.3)
Day-42	8.4 (0.7)	7.7 (2.5)	1.3 (0.1)	8.79 (0.86)	77.6 (0.4)
Barbie Creek:					
LB-42	7.6 (0.5)	4.9 (1.1)	1.1 (0.1)	6.39 (2.03)*	78.2 (0.2)*
BW-42	7.6 (1.1)	5.1 (1.7)	1.1 (0.1)	7.72 (1.22)*	78.1 (0.3)*
Gold Creek:					
MB-42	7.1 (1.0)	4.0 (1.8)	1.0 (0.1)	7.01 (1.02)*	77.9 (0.2)*
Day-42	8.1 (0.5)	5.9 (1.1)	1.1 (0)	6.94 (0.63)*	78.3 (0.3)*
Barbie:					
Feral	8.8 (1.0)	9.0 (3.8)	1.2 (0.2)	4.14 (2.006)	79.3 (0.5)

Values reported are means with SDs in parentheses
* denotes significant difference from Marie Lake Day-0: Mann-Whitney Test, $\alpha = 0.05$

The muscle tissue mercury levels for the caged fish are reported in Table 9. The mean value of mercury for the reference fish at Day-42 was significantly higher than at Day-0. For the caged fish, only the mid-Barbie site had a higher mean mercury level (Figure 3). Derksen (1989) reported the opposite condition occurring in 1988. In 1989, the feral juvenile coho salmon had a mean mercury level of 0.243 $\mu g/g$ (SD=0.083) whereas, in 1988 the mean level in September was 0.171 $\mu g/g$ (SD=0.034). The proportion of methyl mercury to total mercury for the Barbie Creek feral juvenile coho salmon was 78%.

There are differences in the whole fish total mercury levels in Table 10 compared to the fillet muscle total mercury levels in Table 9. The differences likely represent the different way in which the samples were treated (whole vs. fillet). The Marie Lake Day-0 whole fish value differences seem high compared to the other site differences.

TABLE 9: **MUSCLE TISSUE MEAN MERCURY LEVELS IN CAGED AND LAKE PEN JUVENILE COHO SALMON - 1989**

Hg (μg/g, wet weight)	Marie Lake		Barbie Creek			Gold Creek	Barbie Wetland
	Day-0	Day-42	LR-42	BW-42	MB-42	Day-42	Feral
Mean	0.048	0.055*	0.049	0.049	0.053*	0.049	0.243
SD	0.002	0.002	0.003	0.002	0.000	0.001	0.083

Note: n = 8; each caged sample is a composite of 4 dissected fish; BW feral is a composite of 2 fish

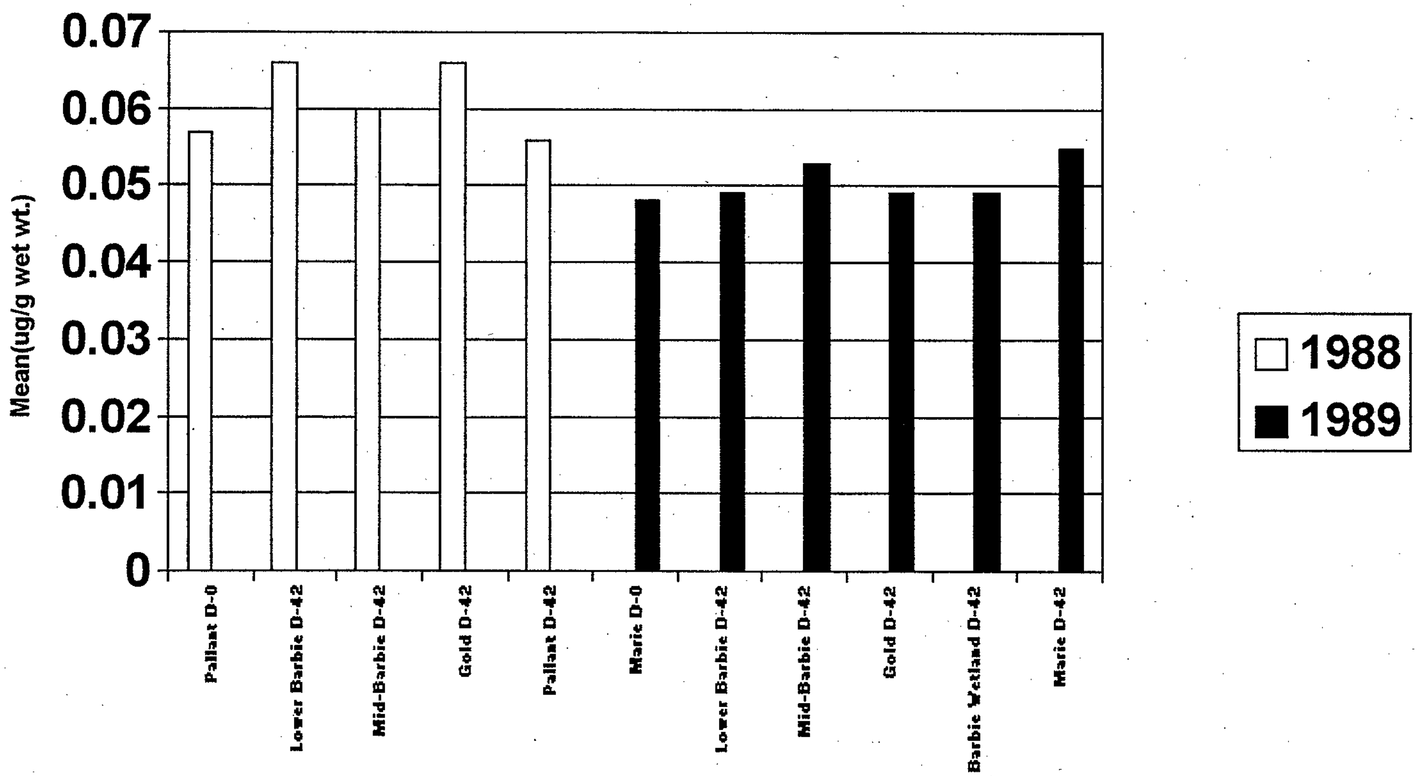
* Denotes significantly different from Day-0 (Mann-Witney Test, $\alpha = 0.05$; Zar, 1984)

TABLE 10: **WHOLE FISH TOTAL AND METHYL MERCURY LEVELS IN CAGED AND LAKE PEN JUVENILE COHO SALMON - 1989**

Hg (μg/g, wet weight)	Marie Lake Day-0	Marie Lake Day-42	Lower Barbie Day-42	Gold Creek Feral	Barbie Wetland Feral
Total	0.075	0.049	0.035	0.081	0.153
Methyl	0.020	0.030	0.030	0.07	0.12
Methyl (% of Total)	27	61	88	86	78

Note: Each sample is a composite of 3 whole fish except Gold Creek is a composite of 2 fish.

FIGURE 3: COMPARISON OF 1988 AND 1989 CAGED JUVENILE COHO SALMON MERCURY LEVELS



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APPENDIX I

1989 CINOLA PROJECT - SURFACE WATER QUALITY

APPENDIX I(a):

1989 CINOLA PROJECT - pH, ACIDITY, AND ALKALINITY

pH (Rel. Units)	STATION				
	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
Aug 1/89	6.4	6.3	6.3	6.9	7.2
Aug 29/89	6.9	6.4	6.8	7.3	7.2
Sept 12/89	7.0	6.9	7.2	7.4	7.4
Mean	6.8	6.5	6.8	7.2	7.3
SD	0.3	0.3	0.5	0.3	0.1
n	3	3	3	3	3

ACIDITY (mg/L)					
Aug 1/89	2.6	3.9	3.9	2.0	1.0
Aug 29/89	3.6	5.9	3.9	2.9	1.3
Sept 12/89	4.1	7.1	6.6	3.1	2.0
Mean	3.4	5.6	4.8	2.7	1.4
SD	0.8	1.6	1.6	0.6	0.5
n	3	3	3	3	3

ALKALINITY (mg/L)					
Aug 1/89	10.0	10.0	11.9	12.9	11.4
Aug 29/89	10.4	9.0	12.9	14.9	13.9
Sept 12/89	10.2	10.2	14.3	15.8	13.3
Mean	10.2	10.1	13.0	14.5	12.9
SD	0.2	0.1	1.2	1.5	1.3
n	3	3	3	3	3

APPENDIX I(a) cont'd.:

1989 CINOLA PROJECT - NITROGEN

AMMONIA (µg/L) — STATION

	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
Aug 1/89	73	40	45	123	27
Aug 29/89	75	51	68	42	<5
Sept 12/89	70	51	99	20	28
Mean	73	47	71	62	20
SD	3	6	27	54	13
n	3	3	3	3	3

NITRITE (µg/L)

Aug 1/89	5	6	<5	<5	<5
Aug 29/89	<5	5	<5	<5	<5
Sept 12/89	<5	5	<5	<5	<5
Mean	5	5	<5	<5	<5
SD	0	1	0	0	0
n	3	3	3	3	3

NITRITE + NITRATE (µg/L)

Aug 1/89	7	<5	<5	<5	<5
Aug 29/89	10	<5	<5	<5	<5
Sept 12/89	10	<5	<5	<5	<5
Mean	9	<5	<5	<5	<5
SD	2	0	0	0	0
n	3	3	3	3	3

TOTAL NITROGEN (µg/L)

Aug 1/89	620	540	500	280	120
Aug 29/89	650	660	620	310	130
Sept 12/89	650	670	770	280	130
Mean	640	623	630	290	127
SD	17	72	135	17	6
n	3	3	3	3	3

APPENDIX I(a) cont'd.:

1989 CINOLA PROJECT - TEMPERATURE AND DISSOLVED OXYGEN

TEMPERATURE (°C)			STATION		
	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
Aug 2/89	17.5	15.5	14.2	15.0*	19.5
Aug 3/89	17.0	15.0	14.2	-	18.5
Aug 29/89	15.0	13.5	13.0	13.5	17.5
Aug 31/89	12.5	12.0	11.5	-	16.0
Sept 12/89	12.0	13.0	11.2	13.0	19.0
Mean	14.8	13.8	12.8	13.8	18.1
SD	2.5	1.4	1.4	1.0	1.4
n	5	5	5	3	5

DISSOLVED OXYGEN (mg/L)

Aug 2/89	3.4	4.5	5.0	9.8*	9.6
Aug 3/89	3.4	4.9	4.8	-	9.9
Aug 29/89	3.6	4.2	4.1	9.1	9.6
Aug 31/89	3.8	2.6	3.6	-	9.9
Sept 12/89	3.3	3.0	2.9	9.8	10.0
Mean	3.5	3.8	4.1	9.6	9.8
SD	0.2	1.0	0.9	0.4	0.2
n	5	5	5	3	5

OXYGEN SATURATION (%)

Aug 2/89	36.6	46.6	50.4	100.0	108.0
Aug 3/89	36.3	50.2	48.3	-	109.0
Aug 29/89	36.9	41.6	40.2	90.2	104.0
Aug 31/89	36.9	24.9	34.1	-	104.0
Sept 12/89	31.6	29.4	27.3	96.1	111.0
Mean	35.7	38.5	40.1	95.4	107.2
SD	2.3	11.0	9.7	4.9	3.1
n	5	5	5	3	5

* = Aug. 1/89

APPENDIX I(a) cont'd.:

1989 CINOLA PROJECT - CHLORIDE, SPECIFIC CONDUCTANCE, SULPHATE AND SULPHIDE

CHLORIDE (mg/L)	STATION				
	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
Aug 1/89	9.1	9.1	9.1	6.6	4.6
Aug 29/89	9.6	9.5	9.6	7.2	4.7
Sept 12/89	10.8	10.9	10.7	7.8	5.3
Mean	9.8	9.8	9.8	7.2	4.9
SD	0.9	0.9	0.8	0.6	0.4
n	3	3	3	3	3

CONDUCTIVITY (μmho/cm)

Aug 1/89	58	58	63	49.5	44.5
Aug 29/89	68	58	68	58	53
Sept 12/89	63	63	70	60	53
Mean	63	60	67	56	50
SD	5	3	4	6	5
n	3	3	3	3	3

SULPHATE (mg/L)

Aug 1/89	10	12	11	5	3
Aug 29/89	12	12	13	7	4
Sept 12/89	8	10	10	5	2
Mean	10	11	11	6	3
SD	2	1	2	1	1
n	3	3	3	3	3

SULPHIDE (mg/L)

Aug 1/89	-	-	-	-	-
Aug 29/89	<0.01	<0.01	<0.01	<0.01	<0.01
Sept 12/89	<0.01	<0.01	<0.01	<0.01	<0.01
Mean	<0.01	<0.01	<0.01	<0.01	<0.01
SD	0	0	0	0	0
n	2	2	2	2	2

APPENDIX I(a) cont'd.:

1989 CINOLA PROJECT - PHOSPHORUS

TOTAL PHOSPHORUS (μg/L) STATION

	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
Aug 1/89	79	68	65	35	5
Aug 29/89	94	63	80	41	4
Sept 12/89	59	64	87	38	5
Mean	77	65	77	38	5
SD	18	3	11	3	1
n	3	3	3	3	3

DISSOLVED PHOSPHORUS (μg/L)

	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
Aug 1/89	44	41	41	27	3
Aug 29/89	52	43	49	29	<2
Sept 12/89	55	46	32	36	5
Mean	50	43	41	31	3
SD	6	3	9	5	2
n	3	3	3	3	3

DISSOLVED ORTHO-PHOSPHATE (μg/L)

	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
Aug 1/89	16	13	15	10	<2
Aug 29/89	15	18	25	18	4
Sept 12/89	14	12	21	13	<2
Mean	15	14	20	14	3
SD	1	3	5	4	1
n	3	3	3	3	3

APPENDIX I(a) cont'd.:

1989 CINOLA PROJECT - RESIDUES AND TURBIDITY

NON-FILTERABLE RESIDUES (mg/L) STATION

	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
Aug 1/89	8	9	6	<5	<5
Aug 29/89	6	10	10	<5	<5
Sept 12/89	7	10	12	<5	<5
Mean	7	10	9	<5	<5
SD	1	1	3	0	0
n	3	3	3	3	3

TOTAL VOLATILE RESIDUE (mg/L)

	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
Aug 1/89	62	56	68	47	22
Aug 29/89	55	86	-	-	25
Sept 12/89	71	83	79	48	23
Mean	63	75	74	48	23
SD	8	17	8	1	2
n	3	3	2	2	3

TURBIDITY (FTU)

	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
Aug 1/89	1.3	0.8	1.3	0.3	<0.1
Aug 29/89	0.9	1.0	3.3	0.6	<0.1
Sept 12/89	0.8	2.8	3.8	0.7	0.2
Mean	1	1.5	2.8	0.5	0.1
SD	0.3	1.1	1.3	0.2	0.1
n	3	3	3	3	3

APPENDIX I(a) cont'd.:

1989 CINOLA PROJECT - HARDNESS

HARDNESS (mg/L $CaCO_3$)	Lower Barbie		Barbie Wetland		Mid-Barbie		Lower Florence		Gold Creek	
	Ca/Mg	Tot.	Ca/Mg	Tot.	Ca/Mg	Tot.	Ca/Mg	Tot.	Ca/Mg	Tot.
Aug 1/89	13.9	21.1	14.6	20.4	17.0	22.9	11.5	14.1	13.3	13.5
	14.1	21.1	-	-	17.5	23.7	11.2	13.6	13.1	13.6
	13.7	20.3	-	-	17.5	23.3	11.4	14.1	13.0	13.2
Aug 29/89	14.4	18.5	15.1	20.8	19.0	27.6	13.9	16.6	14.2	14.5
	14.5	18.4	-	-	18.6	27.1	13.6	16.3	13.8	13.9
	15.0	19.9	-	-	19.0	27.5	14.0	17.1	14.2	14.5
Sept 12/89	15.7	22.5	16.8	23.7	20.8	30.7	15.4	18.3	15.1	15.4
	15.3	21.6	-	-	20.9	31.2	14.4	16.9	15.6	15.8
	14.9	21.5	-	-	20.5	29.8	15.6	18.5	15.6	15.8
Mean	14.6	20.5	15.5	21.6	19.0	27.1	13.4	16.2	14.2	14.5
SD	0.7	1.4	1.2	1.8	1.5	3.2	1.7	1.8	1.0	1.0
n	9	9	3	3	9	9	9	9	9	9

APPENDIX I(a) cont'd.:

1989 CINOLA PROJECT - CARBON

DISSOLVED INORGANIC CARBON (mg/L) STATION

	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
Aug 1/89	2	2	3	2	1
Aug 29/89	2	1	3	3	2
Sept 12/89	3	4	6	3	3
Mean	2	2	4	3	2
SD	1	2	2	1	1
n	3	3	3	3	3

DISSOLVED ORGANIC CARBON (mg/L)

Aug 1/89	27	27	29	15	4
Aug 29/89	29	32	34	17	6
Sept 12/89	29	31	27	15	4
Mean	28	30	30	16	5
SD	1	3	4	1	1
n	3	3	3	3	3

TOTAL INORGANIC CARBON (mg/L)

Aug 1/89	2	3	4	1	1
Aug 29/89	1	2	3	3	3
Sept 12/89*	3	5	7	3	3
Mean	2	3	5	2	2
SD	1	2	2	1	1
n	3	3	3	3	3

* = Appendix VI for complexing capacity results

TOTAL ORGANIC CARBON (mg/L)

Aug 1/89	25	24	27	17	5
Aug 29/89	28	32	31	16	4
Sept 12/89	27	28	26	14	3
Mean	27	28	28	16	4
SD	2	4	3	2	1
n	3	3	3	3	3

APPENDIX I(b):

1989 CINOLA PROJECT - CALCIUM AND MAGNESIUM

CALCIUM (mg/L)	Lower Barbie		Barbie Wetland		Mid-Barbie		Lower Florence		Gold Creek	
	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.
Aug 1/89	3.6	3.4	3.7	3.6	4.5	4.3	2.7	2.4	4.5	4.2
	3.6	3.4	-	-	4.6	4.4	2.6	2.3	4.3	4.1
	3.6	3.3	-	-	4.8	4.5	2.5	2.4	4.5	4.1
Aug 29/89	3.5	3.3	3.7	3.7	4.6	4.6	2.8	2.8	4.8	4.4
	3.6	3.4	-	-	4.7	4.5	2.7	2.7	4.6	4.3
	3.6	3.5	-	-	4.8	4.7	2.6	2.9	4.7	4.4
Sept 12/89	3.6	3.7	3.8	4.0	5.2	5.1	2.9	3.1	4.6	4.7
	3.6	3.6	-	-	5.1	5.2	2.9	2.9	4.5	4.8
	3.7	3.5	-	-	4.9	5.1	2.9	3.1	4.5	4.8
Mean	3.6	3.5	3.7	3.8	4.8	4.7	2.7	2.7	4.6	4.4
SD	0.1	0.1	0.1	0.2	0.2	0.3	0.2	0.3	0.1	0.3
n	9	9	3	3	9	9	9	9	9	9

MAGNESIUM (mg/L)	Lower Barbie		Barbie Wetland		Mid-Barbie		Lower Florence		Gold Creek	
	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.
Aug 1/89	1.6	1.3	1.5	1.4	1.8	1.5	1.6	1.3	0.8	0.7
	1.5	1.4	-	-	1.8	1.6	1.6	1.3	0.8	0.7
	1.6	1.3	-	-	1.9	1.5	1.5	1.3	0.8	0.7
Aug 29/89	1.5	1.5	1.5	1.4	1.8	1.8	1.7	1.7	0.8	0.8
	1.5	1.5	-	-	1.7	1.8	1.7	1.6	0.8	0.7
	1.5	1.5	-	-	1.8	1.8	1.6	1.7	0.8	0.8
Sept 12/89	1.5	1.6	1.5	1.7	1.9	2.0	1.7	1.9	0.7	0.8
	1.6	1.5	-	-	1.9	1.9	1.7	1.8	0.7	0.8
	1.6	1.5	-	-	1.8	1.9	1.7	1.9	0.7	0.9
Mean	1.5	1.5	1.5	1.5	1.8	1.8	1.6	1.6	0.8	0.8
SD	0.1	0.1	0	0.2	0.1	0.2	0.1	0.3	0.1	0.1
n	9	9	3	3	9	9	9	9	9	9

APPENDIX I(b) cont'd:

1989 CINOLA PROJECT - ARSENIC AND SELENIUM

ARSENIC (µg/L)	Lower Barbie		Barbie Wetland		Mid-Barbie		Lower Florence		Gold Creek	
	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.
Aug 1/89	8.2	8.6	8.1	7.4	7.1	9.8	<0.5	<0.5	0.8	1.0
	7.9	9.0	-	-	7.1	9.2	<0.5	<0.5	<0.5	1.0
	8.2	8.1	-	-	7.5	7.4	<0.5	<0.5	<0.5	1.0
Aug 29/89	6.9	7.4	5.4	4.6	11.6	14.1	<0.5	0.5	0.8	1.2
	7.1	6.1	-	-	10.7	13.4	0.6	0.6	0.8	1.6
	7.6	6.3	-	-	10.6	13.0	<0.5	<0.5	0.5	1.3
Sept 12/89	8.7	6.3	7.4	5.3	12.7	13.3	0.6	<0.5	1.0	1.0
	8.4	5.8	-	-	12.8	13.9	<0.5	<0.5	0.7	1.2
	9.0	6.2	-	-	12.9	12.9	<0.5	<0.5	<0.5	1.0
Mean	8.0	7.1	7.0	5.8	10.3	11.9	<0.5	<0.5	0.7	1.1
SD	0.7	1.2	1.4	1.5	2.5	2.4	0	0	0.2	0.2
n	9	9	3	3	9	9	9	9	9	9

SELENIUM (µg/L)	Lower Barbie		Barbie Wetland		Mid-Barbie		Lower Florence		Gold Creek	
	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.
Aug 1/89	0.9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	<0.5	<0.5	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	<0.5	1.4	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Aug 29/89	<0.5	<0.5	<0.5	<0.5	1.6	<0.5	0.5	<0.5	<0.5	<0.5
	<0.5	<0.5	-	-	<0.5	<0.5	<0.5	<0.5	0.9	<0.5
	<0.5	<0.5	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Sept 12/89	<0.5	<0.5	<0.5	<0.5	1.0	<0.5	<0.5	0.5	<0.5	<0.5
	<0.5	<0.5	-	-	1.0	<0.5	<0.5	0.7	<0.5	<0.5
	3.0	<0.5	-	-	0.6	<0.5	2.0	1.0	<0.5	<0.5
Mean	0.8	0.6	<0.5	<0.5	0.7	<0.5	0.7	0.6	<0.5	<0.5
SD	0.8	0.3	0	0	0.4	0	0.5	0.2	0.1	0
n	9	9	3	3	9	9	9	9	9	9

APPENDIX I(b) cont'd:

1989 CINOLA PROJECT - IRON AND MANGANESE

IRON (mg/L)	Lower Barbie		Barbie Wetland		Mid-Barbie		Lower Florence		Gold Creek	
	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.
Aug 1/89	4.73	2.52	3.93	1.89	3.63	1.89	1.53	0.793	0.182	0.076
	4.62	2.43	-	-	3.75	1.93	1.49	0.767	0.166	0.078
	4.61	2.25	-	-	4.03	1.86	1.44	0.870	0.180	0.074
Aug 29/89	4.10	1.28	3.46	1.85	4.84	2.85	1.78	0.862	0.141	0.064
	4.15	1.21	-	-	4.92	2.85	1.75	0.880	0.133	0.059
	4.10	1.66	-	-	5.03	2.83	1.74	0.990	0.124	0.060
Sept 12/89	3.94	2.19	3.98	2.13	5.95	3.23	1.68	0.917	0.075	0.049
	4.05	2.02	-	-	5.79	3.63	1.66	0.822	0.083	0.051
	4.09	2.24	-	-	5.57	3.22	1.69	0.886	0.078	0.049
Mean	4.27	1.98	3.79	1.96	4.83	2.70	1.64	0.865	0.129	0.062
SD	0.30	0.48	0.29	0.15	0.87	0.66	0.12	0.067	0.043	0.012
n	9	9	3	3	9	9	9	9	9	9

MANGANESE (mg/L)	Lower Barbie		Barbie Wetland		Mid-Barbie		Lower Florence		Gold Creek	
	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.
Aug 1/89	0.561	0.476	0.162	0.148	0.294	0.271	0.037	0.024	0.030	0.020
	0.550	0.485	-	-	0.302	0.272	0.037	0.022	0.029	0.019
	0.560	0.467	-	-	0.311	0.272	0.035	0.025	0.030	0.019
Aug 29/89	0.357	0.260	0.145	0.114	0.514	0.497	0.044	0.026	0.026	0.013
	0.362	0.259	-	-	0.523	0.488	0.043	0.027	0.026	0.012
	0.360	0.271	-	-	0.532	0.502	0.043	0.029	0.026	0.012
Sept 12/89	0.486	0.359	0.173	0.171	0.682	0.637	0.041	0.030	0.022	0.011
	0.426	0.339	-	-	0.679	0.663	0.042	0.028	0.021	0.012
	0.422	0.341	-	-	0.667	0.657	0.042	0.030	0.021	0.012
Mean	0.454	0.362	0.160	0.144	0.500	0.473	0.040	0.027	0.026	0.014
SD	0.088	0.093	0.014	0.029	0.163	0.166	0.003	0.003	0.004	0.004
n	9	9	3	3	9	9	9	9	9	9

APPENDIX I(b) cont'd:

1989 CINOLA PROJECT - ALUMINUM AND SILICON

ALUMINUM (mg/L)	Lower Barbie		Barbie Wetland		Mid-Barbie		Lower Florence		Gold Creek	
	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.		Diss.	Diss.
Aug 1/89	0.63	0.31	0.64	0.38	0.62	0.34	0.34	0.20	0.06	<0.05
	0.62	0.30	-	-	0.70	0.40	0.34	0.18	0.07	<0.05
	0.63	0.29	-	-	0.68	0.35	0.34	0.20	0.06	<0.05
Aug 29/89	0.59	0.24	0.64	0.39	0.64	0.44	0.34	0.20	0.06	<0.05
	0.58	0.22	-	-	0.62	0.44	0.35	0.18	0.09	<0.05
	0.56	0.27	-	-	0.66	0.44	0.29	0.21	<0.05	<0.05
Sept 12/89	0.63	0.38	0.63	0.50	0.65	0.51	0.26	0.20	<0.05	<0.05
	0.65	0.35	-	-	0.66	0.45	0.26	0.17	<0.05	<0.05
	0.62	0.34	-	-	0.56	0.42	0.30	0.21	<0.05	<0.05
Mean	0.61	0.30	0.64	0.42	0.64	0.42	0.31	0.19	0.6	<0.05
SD	0.03	0.05	0.01	0.07	0.04	0.05	0.04	0.01	0.1	0
n	9	9	3	3	9	9	9	9	9	9

SILICON (mg/L)	Lower Barbie		Barbie Wetland		Mid-Barbie		Lower Florence		Gold Creek	
	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.
Aug 1/89	2.41	2.13	3.70	3.59	3.69	3.57	5.15	4.80	1.12	1.06
	2.39	2.11	-	-	3.79	3.60	5.09	4.75	1.11	1.04
	2.35	2.09	-	-	3.89	3.58	4.81	4.75	1.13	1.02
Aug 29/89	2.65	2.46	4.13	3.82	3.94	3.96	5.35	5.45	1.14	1.08
	2.73	2.41	-	-	4.00	3.99	5.32	5.34	1.19	1.09
	2.66	2.44	-	-	4.10	4.02	5.26	5.34	1.11	1.08
Sept 12/89	3.05	3.05	4.37	4.75	4.43	4.28	5.63	6.04	1.06	1.11
	3.10	2.94	-	-	4.36	4.43	5.42	5.77	1.07	1.13
	3.06	2.89	-	-	4.17	4.35	5.56	6.15	1.09	1.13
Mean	2.71	2.50	4.07	4.05	4.04	3.98	5.29	5.38	1.11	1.08
SD	0.30	0.37	0.34	0.61	0.25	0.34	0.25	0.54	0.04	0.04
n	9	9	3	3	9	9	9	9	9	9

APPENDIX I(b) cont'd:

1989 CINOLA PROJECT - COPPER AND CADMIUM

COPPER (µg/L)	Lower Barbie		Barbie Wetland		Mid-Barbie		Lower Florence		Gold Creek	
	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.
Aug 1/89	0.7	<0.5	1.1	1.4	1.0	0.6	1.3	<0.5	<0.6	<0.5
	1.0	<0.5	-	-	0.9	0.9	0.6	<0.5	<0.6	<0.5
	0.9	<0.5	-	-	3.2	0.6	1.2	<0.5	<0.6	<0.5
Aug 29/89	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5
	<0.6	<0.5	-	-	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5
	<0.6	<0.5	-	-	0.9	<0.5	<0.6	<0.5	<0.6	<0.5
Sept 12/89	<0.6	<0.5	<0.6	<0.5	2.0	<0.5	0.7	<0.5	<0.6	<0.5
	1.0	<0.5	-	-	2.0	<0.5	0.7	<0.5	<0.6	<0.5
	1.0	<0.5	-	-	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5
Mean	0.8	<0.5	0.8	0.8	1.3	0.6	0.8	<0.5	<0.6	<0.5
SD	0.2	0	0.3	0.5	0.9	0.1	0.3	0	0	0
n	9	9	3	3	9	9	9	9	9	9

CADMIUM (µg/L)	Lower Barbie		Barbie Wetland		Mid-Barbie		Lower Florence		Gold Creek	
	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.
Aug 1/89	<0.1	<0.1	0.4	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	<0.1	<0.1	-	-	<0.1	0.2	<0.1	<0.1	<0.1	<0.1
	<0.1	<0.1	-	-	0.2	0.2	<0.1	0.1	<0.1	0.2
Aug 29/89	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	<0.1	<0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	<0.1	<0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sept 12/89	0.4	<0.1	0.2	0.3	0.5	<0.1	<0.1	<0.1	<0.1	<0.1
	0.9	<0.1	-	-	0.2	<0.1	<0.1	<0.1	<0.1	<0.1
	0.6	<0.1	-	-	<0.1	<0.1	0.2	<0.1	<0.1	<0.1
Mean	0.3	<0.1	0.2	0.2	0.2	0.1	<0.1	<0.1	<0.1	<0.1
SD	0.3	0	0.2	0.1	0.1	0	0	0	0	0
n	9	9	3	3	9	9	9	9	9	9

APPENDIX I(b) cont'd:

1989 CINOLA PROJECT - LEAD AND LOW LEVEL MERCURY

LEAD (μg/L)	Lower Barbie		Barbie Wetland		Mid-Barbie		Lower Florence		Gold Creek	
	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.
Aug 1/89	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5
	<0.6	<0.5	-	-	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5
	<0.6	<0.5	-	-	<0.6	0.8	<0.6	<0.5	<0.6	<0.5
Aug 29/89	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5
	<0.6	<0.5	-	-	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5
	<0.6	<0.5	-	-	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5
Sept 12/89	<0.6	<0.5	-	<0.5	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5
	<0.6	<0.5	-	-	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5
	<0.6	<0.5	-	-	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5
Mean	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5	<0.6	<0.5
SD	0	0	0	0	0	0.1	0	0	0	0
n	9	9	2	3	9	9	9	9	9	9

LOW LEVEL MERCURY (mg/L)	Lower Barbie	Barbie Wetland	Mid-Barbie	Lower Florence	Gold Creek	Yakoun River
	Total	Total	Total	Total	Total	Total
Aug 1/89	18	14	9	13	<5	7
Aug 29/89	9	12	<5	10	11	9
Sept 12/89	11	11	96*	10	6	9
Mean	13	12	37	11	7	8
SD	5	2	51	2	3	1
n	3	3	3	3	3	3

* = not enough sample to confirm

APPENDIX II

1989 CINOLA PROJECT - SEDIMENT QUALITY

APPENDIX II:

1989 CINOLA PROJECT - SEDIMENT TOTAL AND METHYL MERCURY, VOLATILE RESIDUE, AND NITROGEN

TOTAL MERCURY (μg/g)	STATION			
	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	GOLD CREEK
Aug 30/89	0.286	0.220	0.068	0.068

METHYL MERCURY (μg/g)	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	GOLD CREEK	WETLAND* OUTFLOW
Aug 30/89	0.0007	0.0024	<0.0001	0.0015	0.0379
(sample duplicates)	0.0012	0.0025	<0.0001	0.0013	0.0383

* = continuous flow centrifuge concentrated suspended solids sample

VOLATILE RESIDUE (%)	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	GOLD CREEK
Aug 30/89	34.90	60.80	2.96	41.60

TOTAL NITROGEN (μg/g)	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	GOLD CREEK
Aug 30/89	6,500	12,000	670	6,600

APPENDIX II cont'd:

1989 CINOLA PROJECT - REDOX AND HETEROTROPHIC BACTERIA

REDOX (mv)	STATION				
	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
Aug 1/89	+75	+250	+100	-	-50
	-10	+220	+150	-	+20
	+90	+180	+150	-	+60
Aug 29/89	+80	+90	+140	-	+130
	+70	+150	+250	-	+210
	+60	-40	+210	-	+100
Sept 12/89	+150	+180	+230	-	+80
	+90	-20	+210	-	+230
	+150	+50	+150	-	+120
Median	+80	+150	+150		+100

HETEROTROPHIC BACTERIA (CFU/g, sediment; CFU/L, water)

	LOWER BARBIE	BARBIE WETLAND	MID-BARBIE	LOWER FLORENCE	GOLD CREEK
Aug 1/89					
Sediment	800,000	540,000	260,000	-	200,000
Water	31,000	94,000	49,000	-	3,000
Aug 29/89					
Sediment	750,000	-	37,000	-	40,000
Water	92,000	8,600	5,600	-	69

APPENDIX III

1989 CINOLA PROJECT - FISH TISSUE QUALITY

APPENDIX III(a):

1989 CINOLA PROJECT - WHOLE FISH MERCURY LEVELS

MERCURY (μg/g)	MARIE LAKE DAY-0	MARIE LAKE DAY-42	LOWER BARBIE DAY-42	GOLD CREEK DAY-42	GOLD CREEK FERAL	BARBIE WETLAND FERAL
Total (wet wt.)	0.075	0.049	0.035	0.036	0.081	0.153
Total (dry wt.)	0.266	0.182	0.141	0.140	0.358	0.721
Methyl (wet wt.)	0.02	0.03	0.03	0.02	0.07	0.12
Methyl (dry wt.)	0.08	0.10	0.10	0.09	0.30	0.55
% Moisture	72	73.1	75.2	74	77.3	78.8

NOTE: each sample was a composite of 3 whole fish except Gold Creek which was a composite of 2.

REFERENCE STANDARD DORM-1	TOTAL MERCURY (μg/g, dry wt.)
Replicate 1	0.737
Replicate 2	0.735
Replicate 3	0.675
Mean	0.716
SD	0.035
n	3

APPENDIX III(b):

1989 CINOLA PROJECT - COMPOSITE FISH MUSCLE TISSUE TOTAL MERCURY LEVELS

SAMPLE	MARIE LAKE DAY-0		MARIE LAKE DAY-42		LOWER BARBIE DAY-42		BARBIE WETLAND DAY-42		MID-BARBIE DAY-42		GOLD CREEK DAY-42		BARBIE WETLAND FERAL	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
1	0.225	0.051	0.223	0.052	0.230	0.050	0.220	0.049	0.240	0.053	0.222	0.048	0.610	0.128
2	0.202	0.045	0.235	0.053	0.213	0.047	0.218	0.049	0.234	0.052	0.228	0.049	1.050	0.217
3	0.207	0.048	0.242	0.055	0.239	0.051	0.230	0.050	0.236	0.053	0.233	0.050	0.999	0.205
4	0.196	0.045	0.247	0.054	0.237	0.052	0.230	0.051	0.239	0.052	0.223	0.049	1.260	0.258
5	0.206	0.048	0.245	0.053	0.230	0.050	0.223	0.049	0.242	0.053	0.218	0.049	0.982	0.211
6	0.199	0.045	0.260	0.059	0.200	0.044	0.212	0.046	0.237	0.053	0.221	0.049	1.960	0.402
7	0.218	0.049	0.238	0.055	0.226	0.049	0.214	0.046	0.244	0.053	0.218	0.047	1.590	0.313
8	0.215	0.049	0.252	0.056	0.225	0.049	0.231	0.050	0.239	0.053	0.239	0.051	1.000	0.210
Mean	0.209	0.048	0.243	0.055	0.225	0.049	0.222	0.049	0.239	0.053	0.225	0.049	1.181	0.243
SD	0.010	0.002	0.011	0.002	0.013	0.003	0.007	0.002	0.003	0	0.008	0.001	0.419	0.083
n	8	8	8	8	8	8	8	8	8	8	8	8	8	8

NOTE: each sample was a composite of 4 muscle fillets

REFERENCE STANDARD TUNA-50	TOTAL MERCURY* (μg/g, dry weight)
Replicate 1	0.888
Replicate 2	0.915
Replicate 3	0.840
Mean	0.881
SD	0.038
n	3

* = certified value = 0.95 ± 0.1 μg/g

APPENDIX III(b) cont'd:

1989 CINOLA PROJECT - MOISTURE CONTENT OF COHO MUSCLE TISSUE

SAMPLE	MARIE LAKE DAY-0	MARIE LAKE DAY-42	LOWER BARBIE DAY-42	BARBIE WETLAND DAY-42	MID-BARBIE DAY-42	GOLD CREEK DAY-42	BARBIE WETLAND FERAL DAY-42
1	77.4	77.6	78.4	77.8	77.8	78.5	79.0
2	77.5	77.3	78.1	77.6	77.7	78.6	79.3
3	76.8	77.4	78.5	78.4	77.6	78.4	79.5
4	77.1	78.0	78.1	78.0	78.2	78.0	79.5
5	76.6	78.4	78.1	78.0	78.0	77.7	78.5
6	77.4	77.4	78.2	78.1	77.7	78.0	79.5
7	77.5	77.1	78.1	78.4	78.2	78.6	80.3
8	77.3	77.6	78.3	78.4	77.7	78.5	79.0
Mean	77.2	77.6	78.2	78.1	77.9	78.3	79.3
SD	0.3	0.4	0.2	0.3	0.2	0.3	0.5
n	8	8	8	8	8	8	8

NOTE: each sample was a composite of 4 muscle fillets

APPENDIX III(c):

1989 CINOLA PROJECT - PROXIMATE ANALYSIS - CAGED JUVENILE COHO

LENGTH (cm) & WEIGHT (gm)	MARIE LAKE DAY-0		MARIE LAKE DAY-42		LOWER BARBIE DAY-42		BARBIE WETLAND DAY-42		MID-BARBIE DAY-42		GOLD CREEK DAY-42		BARBIE WETLAND FERAL DAY-42	
	L	Wt	L	Wt	L	Wt	L	Wt	L	Wt	L	Wt	L	Wt
1	7.4	4.6	8.3	7.2	8.2	6.2	7.5	4.9	7.7	4.7	8.1	5.9	9.9	12.5
2	7.3	4.6	8.4	6.9	7.7	4.8	8.5	6.7	7.5	4.4	8.6	7.4	8.3	6.4
3	8.3	6.0	7.8	6.1	6.8	3.2	8.4	6.8	6.4	3.0	7.6	4.8	7.7	5.3
4	7.9	5.4	9.5	12.1	8.0	5.5	5.8	2.6	8.3	6.4	7.6	4.9	9.8	13.7
5	7.6	4.9	8.1	6.1	7.5	5.0	7.6	4.6	5.7	1.5	8.4	6.5	8.5	6.9
Mean	7.7	5.1	8.4	7.7	7.6	4.9	7.6	5.1	7.1	4.0	8.1	5.9	8.8	9.0
SD	0.4	0.6	0.6	2.5	0.5	1.1	1.1	1.7	1.0	1.8	0.5	1.1	1.0	3.8
n	5	5	5	5	5	5	5	5	5	5	5	5	5	5

LIPID (%) & COND. FACT.	MARIE LAKE DAY-0		MARIE LAKE DAY-42		LOWER BARBIE DAY-42		BARBIE WETLAND DAY-42		MID-BARBIE DAY-42		GOLD CREEK DAY-42		BARBIE WETLAND FERAL DAY-42	
	Lip.	CF	Lip.	CF	Lip.	CF	Lip.	CF	Lip.	CF	Lip.	CF	Lip.	CF
1	9.45	1.1	9.99	1.3	7.08	1.1	6.04	1.2	7.44	1.0	6.81	1.1	5.94	1.3
2	10.96	1.2	8.51	1.2	5.40	1.1	7.87	1.1	5.95	1.0	7.28	1.2	2.42	1.1
3	8.98	1.0	8.71	1.3	4.22	1.0	9.02	1.1	6.56	1.1	6.85	1.1	1.64	1.2
4	10.52	1.1	9.08	1.4	9.53	1.1	7.00	1.3	8.57	1.1	7.73	1.1	7.90	1.5
5	8.66	1.1	7.64	1.1	5.71	1.2	8.66	1.0	6.55	0.8	6.02	1.1	2.81	1.1
Mean	9.71	1.1	8.79	1.3	6.39	1.1	7.72	1.1	7.01	1.0	6.94	1.1	4.14	1.2
SD	0.99	0.1	0.86	0.1	2.03	0.1	1.22	0.1	1.02	0.1	0.63	0	2.66	0.2
n	5	5	5	5	5	5	5	5	5	5	5	5	5	5

APPENDIX III(d):

1989 CINOLA PROJECT - CAGED FISH WEIGHT, LENGTH, AND CONDITION FACTOR

	MARIE LAKE DAY-0		
	Fork Length (cm)	Weight (g)	Cond. Fact.
	7.4	4.6	1.1
	7.3	4.6	1.2
	8.3	6.0	1.0
	7.9	5.4	1.1
	7.6	4.9	1.1
	7.0	4.1	1.2
	6.9	3.6	1.1
	6.9	4.2	1.3
	7.3	4.0	1.0
	6.4	2.8	1.1
	7.2	4.2	1.1
	7.4	4.7	1.2
	7.8	5.1	1.1
	6.8	3.1	1.0
	7.2	4.2	1.1
	7.1	4.1	1.1
	7.2	4.2	1.1
	8.0	5.5	1.1
	7.8	5.0	1.1
	6.5	3.2	1.2
	8.4	6.4	1.1
	7.2	4.2	1.1
	7.2	4.1	1.1
	7.2	4.2	1.1
	8.0	5.8	1.1
	6.8	3.5	1.1
	8.0	6.0	1.2
	7.6	4.8	1.1
	6.9	3.3	1.0
	7.6	5.2	1.2
	7.8	5.3	1.1
	7.9	5.7	1.2
	7.0	4.0	1.2
	7.9	5.6	1.1
	7.0	3.7	1.1
	7.0	4.1	1.2
	8.1	6.0	1.1
	6.5	3.0	1.1
	7.1	4.1	1.1
	7.8	5.5	1.2
mean	7.4	4.6	1.1
SD	0.5	0.9	0.1
n	40	40	40

	MARIE LAKE DAY-42		
	Fork Length (cm)	Weight (g)	Cond. Fact.
	8.3	7.2	1.3
	8.4	6.9	1.2
	7.8	6.1	1.3
	9.5	12.1	1.4
	8.1	6.1	1.1
	9.3	9.5	1.2
	8.3	7.1	1.2
	7.9	6.0	1.2
	8.8	8.5	1.2
	8.9	8.5	1.2
	8.3	6.8	1.2
	8.4	7.2	1.2
	9.2	7.9	1.0
	8.3	7.1	1.2
	9.2	8.8	1.1
	8.6	7.6	1.2
	8.5	7.5	1.2
	8.2	6.3	1.1
	7.5	4.6	1.1
	8.9	7.2	1.0
	8.5	7.5	1.2
	8.1	6.0	1.1
	8.2	5.8	1.1
	8.4	6.7	1.1
	7.7	4.7	1.0
	8.7	7.4	1.1
	6.9	3.8	1.2
	8.3	6.4	1.1
	9.9	11.4	1.2
	8.4	5.6	0.9
	8.6	6.8	1.1
	8.3	5.8	1.0
	8.6	6.8	1.1
	8.4	6.3	1.1
	8.4	6.5	1.1
	9.0	7.1	1.0
	8.4	7.7	1.3
	9.1	7.5	1.0
	8.9	7.4	1.0
	8.3	6.1	1.1
mean	8.5	7.1	1.1
SD	0.5	1.6	0.1
n	40	40	40

APPENDIX III(d) cont'd.:

1989 CINOLA PROJECT - CAGED FISH WEIGHT, LENGTH, AND CONDITION FACTOR

	GOLD CREEK DAY-42		
	YSI DO 9.6 - 10 mg/L % SAT. 103 - 111 TEMP. 16 - 19.5°C		
	Fork Length (cm)	Weight (g)	Cond. Fact.
	8.1	5.9	1.1
	8.6	7.4	1.2
	7.6	4.8	1.1
	7.6	4.9	1.1
	8.4	6.5	1.1
	8.3	7.1	1.2
	7.8	5.6	1.1
	8.7	7.5	1.1
	7.8	5.0	1.1
	7.9	5.4	1.1
	9.0	8.2	1.1
	8.4	6.6	1.1
	8.6	7.1	1.1
	8.8	7.9	1.2
	8.1	5.3	1.0
	8.3	5.7	1.0
	9.3	8.3	1.0
	8.1	6.2	1.2
	7.3	4.3	1.1
	7.4	4.5	1.1
	9.2	7.4	1.0
	9.7	10.5	1.2
	8.1	6.4	1.2
	5.5	1.6	1.0
	8.2	6.8	1.2
	7.6	5.1	1.2
	7.5	5.1	1.2
	8.3	6.0	1.0
	8.4	6.4	1.1
	8.0	5.8	1.1
	7.0	3.8	1.1
	7.9	5.8	1.2
	7.2	4.4	1.2
	7.3	5.0	1.3
	6.9	3.5	1.1
	6.7	3.3	1.1
	7.5	5.0	1.2
	8.1	5.4	1.0
	8.5	5.9	1.0
mean	8.0	5.8	1.1
SD	0.8	1.6	0.1
n	39	39	39

	LOWER BARBIE DAY-42		
	YSI DO 3.3 - 3.8 mg/L % SAT. 32 - 37 TEMP 12 - 17.4°C		
	Fork Length (cm)	Weight (g)	Cond. Fact.
	8.2	6.2	1.1
	7.7	4.8	1.1
	6.8	3.2	1.0
	8.0	5.5	1.1
	7.5	5.0	1.2
	7.0	4.0	1.2
	7.5	4.8	1.1
	7.5	4.5	1.1
	7.7	5.0	1.1
	7.2	3.9	1.0
	8.2	5.8	1.1
	8.0	5.3	1.0
	7.7	5.1	1.1
	8.5	6.6	1.1
	8.0	5.6	1.1
	7.9	4.9	1.0
	7.3	3.9	1.0
	7.0	3.4	1.0
	8.0	5.1	1.0
	7.2	3.7	1.0
	7.3	4.0	1.0
	9.3	9.1	1.1
	8.3	6.4	1.1
	7.9	5.3	1.1
	8.3	5.9	1.0
	7.7	4.6	1.0
	7.5	4.4	1.0
	7.6	4.7	1.1
	8.3	6.3	1.1
	7.8	5.2	1.1
	8.3	5.6	1.0
	7.0	3.3	1.0
	8.5	6.8	1.1
	7.5	4.3	1.0
	7.5	4.3	1.0
	7.0	3.8	1.1
	8.0	5.4	1.1
	8.0	4.8	0.9
	7.5	4.5	1.1
	7.4	4.2	1.0
mean	7.7	5.0	1.1
SD	0.5	1.1	0.1
n	40	40	40

APPENDIX III(d)cont'd.:

1989 CINOLA PROJECT - CAGED FISH WEIGHT, LENGTH, AND CONDITION FACTOR

	BARBIE WETLAND DAY-42		
	YSI DO 2.6 - 4.9 mg/L % SAT. 25 - 50 TEMP. 12 - 15.5°C		
	Fork Length (cm)	Weight (g)	Cond. Fact.
	7.5	4.9	1.2
	8.5	6.7	1.1
	8.4	6.8	1.1
	5.8	2.6	1.3
	7.6	4.6	1.0
	8.0	5.2	1.0
	8.7	7.0	1.1
	8.2	5.8	1.1
	7.9	5.5	1.1
	8.3	6.4	1.1
	8.6	7.0	1.1
	8.9	7.8	1.1
	7.3	4.0	1.0
	6.0	2.7	1.3
	8.6	7.1	1.1
	7.6	4.6	1.0
	7.6	5.0	1.1
	8.2	6.2	1.1
	8.3	5.9	1.0
	8.0	5.2	1.0
	7.4	4.7	1.2
	8.3	6.2	1.1
	7.5	4.7	1.1
	9.2	8.3	1.1
	7.5	5.0	1.2
	7.8	5.6	1.2
	7.8	5.1	1.1
	8.3	6.6	1.2
	8.0	5.5	1.1
	8.6	6.9	1.1
	8.2	5.8	1.1
	8.0	4.7	0.9
	8.2	5.8	1.1
	7.3	4.2	1.1
	8.0	6.2	1.2
	7.1	4.3	1.2
	7.3	4.4	1.1
mean	7.9	5.5	1.1
SD	0.7	1.3	0.1
n	37	37	37

	MID-BARBIE DAY-42		
	YSI DO 2.9 - 5 mg/L % SAT. 27 - 50 TEMP 11.2 - 14.2°C		
	Fork Length (cm)	Weight (g)	Cond. Fact.
	7.7	4.7	1.0
	7.5	4.4	1.0
	6.4	3.0	1.1
	8.3	6.4	1.1
	5.7	1.5	0.8
	6.1	2.2	1.0
	7.2	4.2	1.1
	7.3	4.9	1.3
	8.1	6.2	1.2
	7.9	4.8	1.0
	8.5	6.2	1.0
	7.8	5.2	1.1
	7.5	4.7	1.1
	8.1	6.1	1.1
	7.6	4.9	1.1
	7.4	3.9	1.0
	7.9	5.0	1.0
	8.4	6.3	1.1
	7.2	5.1	1.4
	7.1	3.5	1.0
	6.4	2.7	1.0
	7.4	4.3	1.1
	9.1	8.2	1.1
	7.5	4.1	1.0
	8.4	6.5	1.1
	7.3	3.8	1.0
	8.0	5.1	1.0
	7.2	3.8	1.0
	7.8	4.9	1.0
	7.1	4.3	1.2
	8.2	6.1	1.1
	6.1	2.0	0.9
	7.2	3.5	0.9
	8.6	6.8	1.1
	8.1	5.1	1.0
	8.0	5.5	1.1
	8.5	6.7	1.1
mean	7.6	4.8	1.1
SD	0.8	1.5	0.1
n	37	37	37

APPENDIX III(e):

1989 CINOLA PROJECT - COMPOSITE FISH LIVER METAL ANALYSIS

METALS (μg/g, dry wt.)	MARIE LAKE DAY-0	MARIE LAKE DAY-42	LOWER BARBIE DAY-42	BARBIE WETLAND DAY-42	MID-BARBIE DAY-42	GOLD CREEK DAY-42	BARBIE WETLAND FERAL DAY-42
Al	<5	<4	<4	<4	5	<4	10
As	<5	<4	<4	<4	<4	<4	<9
Ca	470	460	590	680	780	450	620
Cd	<0.5	<0.4	<0.4	<0.4	<0.4	<0.4	<0.9
Cu	29.1	29	27.6	24.3	28.1	32.9	18.9
Fe	250	438	359	418	421	404	1,490
Mg	700	740	720	750	750	710	720
Mn	5.5	5.7	7.1	5.5	7.9	5.8	8.2
Pb	<5	<4	<4	<4	<4	<4	<9
Se	<5	<4	<4	<4	<4	<4	<9
Si	<5	<4	<4	<4	5	<4	<9
Zn	103	116	105	116	132	109	146
% Moisture	72.4	73.3	72.5	71.5	70.9	72.4	70.6
	REFERENCE TISSUE RESULTS						
	DOLT-1	DOLT-1	DOLT-1	MEAN	SD	n	
Al	6	<4	6	5.3	1.2	3	
As	13	13	13	13	0	3	
Ca	480	480	490	483.3	5.8	3	
Cd	4.1	3.9	4.4	4.1	0.3	3	
Cu	19.8	20.2	19.5	19.8	0.4	3	
Fe	685	688	687	686.7	1.5	3	
Mg	1,020	1,030	1,020	1,023.3	5.8	3	
Mn	8.4	8.5	8.4	8.4	0	3	
Pb	<4	<4	<4	<4	0	3	
Se	7	8.5	6	7.2	1.3	3	
Si	<4	<4	5	4.3	0.6	3	
Zn	87.9	85.6	90	87.8	2.2	3	

APPENDIX IV

1989 CINOLA PROJECT - FISH RATION QUALITY

APPENDIX IV:

1989 CINOLA PROJECT - FISH RATION QUALITY

METALS ($\mu g/g$, dry wt.)	BIODIET
Hg	0.082
Al	367
As	<4
Ca	19,800
Cd	0.5
Cu	8.67
Fe	736
Mg	1,810
Mn	49.20
Pb	5
Se	<4
Si	179
Zn	172
% Moisture	18.8

APPENDIX V

1989 CINOLA PROJECT - FISH TRANSPORTATION PARAMETERS

AUGUST 2, 1989

APPENDIX V:

1989 CINOLA PROJECT - FISH TRANSPORTATION PARAMETERS, AUGUST 2, 1989

	TEMPERATURE (°C)		DISSOLVED OXYGEN(mg/L)	
CONTAINER	START	END	START	END
1	19	17	9.6	11.8
2	19	15	9.7	10.6
3	19	16.5	10.0	10.6

NOTE: no mortalities during transport

APPENDIX VI

1989 CINOLA PROJECT - COMPLEXING CAPACITY

Our Reference No. CBR 197

November 27, 1989

Report

Humic Content and Metal Complexing Capacity (CC) of Fresh Waters (Queen Charlotte Islands)

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SUMMARY

The concentrations of humic substances (Aldrich equivalents) for Lower Barbie Creek, Florence Creek, Gold Creek and Yakoun River were found to be 24.7, 15.4, 2.3, and 2.0 mg/L respectively.

Copper complexing capacity values for these samples (in the same order as above) were 122.6, 79.4, 33.7 and 28.9 ppb. Humic content and zinc complexing capacity for Johnson creek were found to be 0.40 mg/L and <0.7 ppb respectively.

TABLE OF CONTENTS

1.0 EXPERIMENTAL

1.1 INTRODUCTION

An indication of the ability of waters to buffer the concentration of free metal ions can be obtained by determining its metal complexing capacity. Copper is usually the metal of choice due to:

- o simple analytical chemistry
- o strong affinity for humic substances
- o effects on biota.

Although humic substances make up only about 50% of the dissolved organic carbon pool in fresh water (Malcolm, 1985) they are the major contributors to metal complexing reactions. Correlations between copper complexing capacity and humic substances content can then help in the assessment of the metal buffering capacity of a given water sample of known humic content.

1.2 EQUIPMENT, REAGENTS AND METHODS

1.2.1. Equipment

- o LKB Biochrom Ultrospec II UV/VIS spectrophotometer
- o Varian atomic absorption spectrometer model AA-475
- o Metrohm polarographic analyzer equipped with a 646 VA processor and a 647 VA multiple mode electrode stand.
- o Orion pH meter model SA-720
- o UV digester equipped with a medium pressure Hanovia Hg lamp.

1.2.2 Reagents

Analytical reagent copper foil (BDH, 99.9%) and zinc (BDH, >99.98%) were used to prepare 1000 ppm stock solutions respectively. Substock solutions were prepared of appropriate concentrations.

Humic acid standard stock solution was prepared by dissolving 50 mg of humic acid (Aldrich) in 50 mL of quartz-distilled Milli-Q water (pH adjusted to 8). A series of standard solutions were prepared by diluting appropriate volumes of the stock solution with quartz-distilled Milli-Q water (pH adjusted to 8).

1.2.3 Quantification of Humic Substances (Humic Acid Aldrich Equivalents)

The determination of humic substances was carried out as described by Carpenter and Smith (1984). Prior to analysis samples were filtered through a 0.2 um MSI mixed ester membrane. Background iron was determined by flame atomic absorption. All samples showed iron content below 2 mg/L. A series of humic acid solutions covering the range from 0 to 50 mg/L was used as a calibration curve. Sample and standard absorbance were measured at 365 nm using LKB Biochrom Ultrospec II UV-VIS spectrometer.

1.2.4 Quantification of Background Copper and Zinc

Water samples were photo-oxidized after acidification for three hours in order to destroy organic matter. Copper and zinc concentrations were determined by differential pulse anodic stripping voltammetry (DPASV) using the standard addition method.

1.2.5 Determination of Copper Complexing Capacity

Copper complexing capacity was determined by titrating the water sample with increasing amounts of standard copper solution. After each copper addition, labile copper was determined by DPASV. The program employed consisted of an equilibration time of two minutes, during which the sample was automatically stirred and purged of air with argon. This was followed by the application of a deposition potential of -400 mV vs Ag/AgCl electrode at the hanging drop mercury electrode (HDME) for two minutes. A rest period of 30 seconds followed, after which a potential scan from -400 mV to 125 mV vs Ag/AgCl was applied. The copper peak appeared at about 20 mV. Control solutions made up of quartz-distilled Milli-Q water were analyzed as described above to give quality control and assurance and, at the same time, to inform on the electrode response to labile copper species. All samples and control solutions were adjusted to pH 5 with addition of acid (Ultra pure Seastar $HClO_4$). A spike of 100 uL of 1M KNO_3 was added to provide a supporting electrolyte.

Titration curves were analyzed by plotting the peak current versus the total concentration of copper added, taking into consideration the initial copper background. Complexing capacity was calculated by the formula CC = -(Bbo-Bo)/Bb1, where CC is the complexing capacity, Bbo and Bo are the intercepts of post-complexing region of the titration curve and the control curves respectively, and Bb1 is the slope of the post-complexing region of the titration curve. A typical titration curve corresponding to sample #10 is shown in Figure 1 in Appendix.

1.2.6 Determination of Zinc Complexing Capacity

Zinc complexing capacity was determined as described for copper. The program used was exactly the same with the exception that the deposition potential was set at -1.150 V vs Ag/AgCl, followed by a potential scan from -1.150 V to -50 mV. The rest of the procedure was as described in 1.2.5. The peak corresponding to zinc appeared at about -1.0 V versus Ag/AgCl.

2.0 RESULTS

2.1 METAL COMPLEXING CAPACITY AND HUMIC ACID CONTENT

TABLE 1

Sample	HA* (mg/L)	C.C.** (moles/L)	C.C.** (ppb)
2	24.7	1.96×10^{-6}	122.6
10	15.4	1.25×10^{-6}	79.4
14	2.3	5.30×10^{-6}	33.7
20	2.0	4.55×10^{-6}	28.9
11	0.40	$< 1.0 \times 10^{-8}$	<0.7

*Aldrich humic acid - equivalents
**Copper complexing capacity with the exception of sample 11 which corresponds to zinc complexing capacity.

Sample identification: Lower Barbie Creek (2), Florence Creek (10), Gold Creek (14), Yakoun River (20) and Johnson Creek (11).

3.0 DISCUSSION

The complexing capacity of fresh waters is mainly due to the ability of humic substances to chelate metal ions. This results in a metal buffering capacity, which plays an important role in controlling trace metal speciation. The humic-complex forms of most metals are not directly bioavailable. This however does not represent a general statement, since certain metal ions do deviate from this behavior, as is the case of mercury and cadmium, which show an increased bioavailability to certain aquatic organisms in the presence of humic matter.

Table 1 summarizes the results of the present study, which indicate the expected pattern. Copper complexing capacity decreases as the concentration of humic acid decreases. Using Aldrich humic acid - equivalents as a surrogate measurement of humic substances in the water samples, an empirical correlation can be derived in which copper complexing capacity is mathematically related to humic content by the equation: $CC = 3.99*HA + 21.9$ (correlation coefficient 0.998, $p < 0.01$); where CC is the copper complexing capacity in parts per billion and HA in the humic acid Aldrich - equivalents in parts per million (see Figure 2 of Appendix).

It must be emphasized that this is an empirical relationship, which is only useful as a way of estimating the complexing capacity in the water samples investigated. It does not have real chemical meaning for two reasons: first, as can be seen in Figure 2, the y-intercept is not zero as would be expected in the absence of humic material, this could be due to the fact that we are using "Aldrich-equivalents" and not the "actual humic concentration" as x-coordinate; and second, it has been shown (Stevenson, 1985; Gamble and Schnitzer, 1974) that it is the carboxyl and phenolic groups present in humic substances, which account for metal binding.

A more valid correlation would involved the concentration (molarity) of carboyxl and phenolic groups (ionized and unionized) as x-coordinate and the copper complexing capacity in molarity units. This would require the determination of the acid-base properties of the humic material present in these samples, as well as its copper complexation reactions. Such a study would result in a mapping of the binding sites present in each of the samples and their ability to complex copper. This, in turn, would permit predictive calculations about copper and other metal ion speciation to be made. Nevertheless, the above described correlation can be used as a first approximation, provided that the measured humic content (Aldrich-equivalents) is within the correlation limits of 2.0 to 24.7 mg/L.

Estimates of the average conditional stability constant for copper-humic complexes as determined by Ruzic's method (Ruzic, 1982) gave a value for logK of 7.0 ($K = 9.84 \times 10^6$), indicating a strong affinity for copper ions.

Zinc complexing capacity was only determined for sample #11 as requested by the client. Its low humic content in comparison with the other samples corroborates the almost zero value, within experimental error, for the zinc complexing capacity. It could be possible to obtain an estimate of the complexing capacity of this sample using copper instead of zinc, since copper interaction with humic substances is stronger than that of zinc. The value for zinc complexing capacity can also be the result of copper ions blocking zinc-binding sites in the original sample. Only a detailed study of copper-zinc competition for binding sites in this sample would reveal if this is a correct assessment.

4.0 REFERENCES

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